National Aeronautics and
Space Administration

Spacecraft/Payload Integration & Evolution Element,
Space Launch System Program
Marshall Space Flight Center AL 35812

Space Launch System (SLS) EM-2 Secondary Payloads 6U & 12U Potential Cubesat Accommodations

WHITEPAPER

March 29, 2019

The following are excerpts from the Space Launch System (SLS) Mission Planner's Guide (ESD 30000 Rev. A, 12/19/18). It is available publicly at https://ntrs.nasa.gov/search.jsp?R=20170005323.

1.0 Lunar Vicinity

For the first SLS crewed mission (planned for EM-2), the SLS Block 1 Interim Cryogenic Upper Stage (ICPS) will insert Orion into an elliptical orbit to support final checkout of the spacecraft, After this, Orion flies a Hybrid Free Return trajectory around the Moon, as shown in Figure 1. Following separation from Orion, ICPS will put itself on a heliocentric disposal trajectory. Deployment of any Secondary Payloads (SPLs) at different ICPS locations may occur during this period.

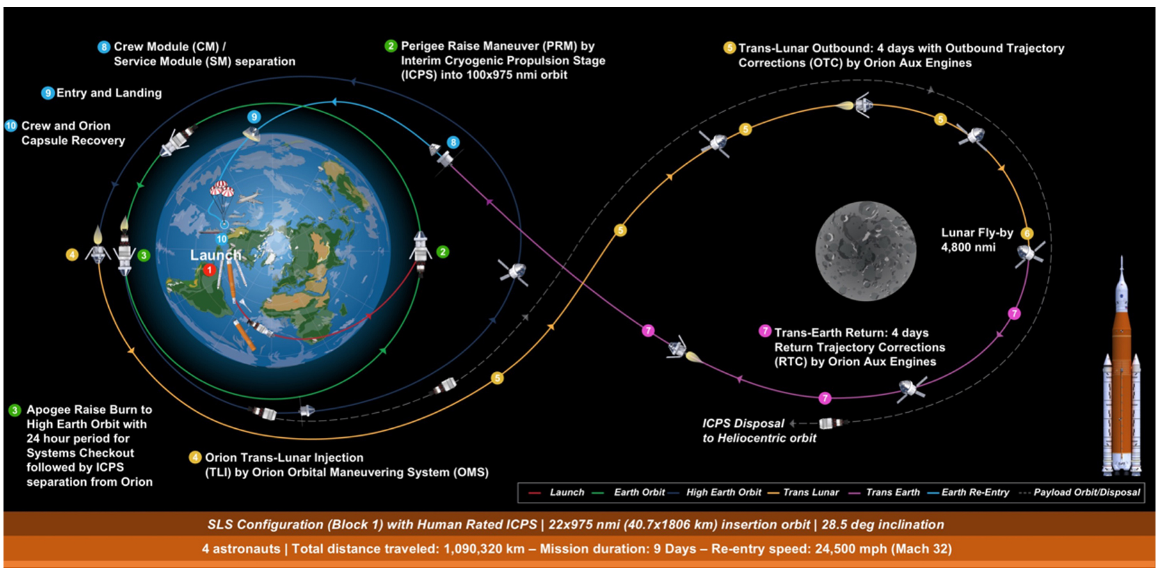

Figure 1 SLS Block 1 Hybrid Free Return Trajectory (EM-2)

2.0 SLS Environments

This section describes the SLS environments to which a spacecraft or payload will be exposed, both during ground processing and in flight.

2.1 Structural Loads

Spacecraft/payload accelerations are estimates from ongoing SLS analysis. Dynamic excitations, occurring predominantly during liftoff and transonic periods of SLS flights, are superimposed on steady-state accelerations from specific mission trajectory analyses to produce combined accelerations that should be used in payload structural design. The combined payload accelerations are a function of launch vehicle characteristics as well as payload dynamic characteristics and mass properties. Representative design load factors for SLS Block 1 payloads are shown in Table 1.

Table 1. Block 1 SPL Component Load Factors Due to Low Frequency Loads

Flight Phases	Vehicle Axial	Vehicle Lateral and Radial
Liftoff through Ascent/Boost	+0.6, -3.5g	±3.0g
Ascent/Core through In-Space	-4.1g	±0.5g

2.2 Thermal Environments

The SLS Block 1 environmental temperature for SPL installed in a dispenser located within the Orion Stage Adapter (OSA) (also known as the Multi-Purpose Crew Vehicle Stage Adapter (MSA)) is shown in Table 2 for pre-launch, Table 3 for ascent, and Table 4 for on-orbit.

Table 2 Block 1 SPL Pre-Launch Environment Temperatures

Mission Phase	Integrated Payload (°F)
Rollout, NO purge, MAX	130
Rollout, NO purge, MIN	26
On-Pad, Purge ON, MAX	101
On-Pad, Purge ON, MIN	29
On-Pad, Tanked, Purge ON, MAX	95
On-Pad, Tanked, Purge ON, MIN	17
On-Pad, Tanked, Purge ON, MAX Time = 0.0 seconds	88
On-Pad, Tanked, Purge, ON, MIN Time = 0.0 seconds	24

Table 3 Block 1 SPL Ascent Environment Temperatures

Mission Phase	Dispenser Temperature Ascent (°F)	Dispenser Temperature On-Orbit (°F) to TLI	Dispenser Temperature Shutdown (°F)
Ascent, MAX	88	90	87
Ascent, MIN	24	18	4

Table 4 Block 1 SPL On-Orbit Environment Temperatures

Mission Phase	Dispenser Temperature TLI to TLI + 24 hours (°F)	Dispenser Temperature TLI + 24 hours thru Lunar Flyby (°F)
On-orbit, MAX	116	130
On-orbit, MIN	6	53

2.3 Internal Acoustics

The SLS Block 1 OSA-Mounted Secondary Payload (SPL) maximum expected internal acoustic environment is shown in Table 5. The internal acoustic environment represents a 95 percent probability, with a 50 percent confidence level and no blanketed section.

Table 5 Block 1 SPL Internal Acoustic Environments, No Blanket Included

1/3-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB re: 20 μPa)
20	115.4
25	120.7
31.5	125.5
40	130.1
50	131.5
63	132.8
80	133.5
100	133.8
125	134.2
160	134.0
200	134.0
250	132.2
315	130.1
400	127.4
500	124.8
630	122.4
800	119.1
1000	116.3
1250	112.9
1600	109.1
2000	106.4

1/3-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB re: 20 μPa)
2500	103.6
3150	101.0
4000	98.0
5000	95.1
6300	92.2
8000	89.4
10000	86.9
Overall Sound Pressure Level	**143.2**

3.0 SLS Contamination and Cleanliness

Launch vehicle hardware that comes into contact with the spacecraft/payload's environment is designed and manufactured according to strict contamination control requirements and guidelines. Ground operations at the launch site have been designed to ensure a clean environment for the spacecraft/payload. Cleanliness requirements for each spacecraft/payload will be evaluated on a case-by-case basis. All SLS payloads will follow specified contamination control procedures to prevent particle release and minimize Foreign Object Debris to ensure mission safety and success.

Cleanliness levels will be categorized as "generally" or "visibly" clean, to meet a wide range of cleanliness needs. A "generally" clean level ensures that parts are free of manufacturing residue, dirt, oil, grease, processing debris and any other extraneous contamination. This generally clean level should be assigned to hardware that is not sensitive to contamination and can be easily and quickly cleaned.

"Visibly" clean hardware will meet the requirements of the generally clean level and will be cleaned and qualitatively verified to be free of all particulate and non-particulate material visible to the normal eye. Hardware cleaned to this level will be continuously protected using heat-sealed double bagging until the hardware is integrated or assembled into the next level of assembly in a clean-room environment. If the item is too large in size or weight, the visibly clean surfaces shall be prepackaged to cover all exposed critical surfaces.

The first level is Standard, which will have an incident light level greater or equal to 500 lm/m2 with an inspection distance of 5 to 10 feet (1.5 to 3 m). The next level, Sensitive, will have the same incident light level as Standard, but with a closer inspection distance of 2 to 4 feet (0.6 to 1.2 m).

4.0 Spacecraft/Payload Interfaces

Figure 2 provides nominal Integrated Spacecraft/Payload Element (ISPE) details for SLS Block 1; the ISPE includes all equipment between the SLS Core Stage and Orion for the crew configuration and all equipment above the SLS Core Stage for the cargo configuration (shown for reference only).

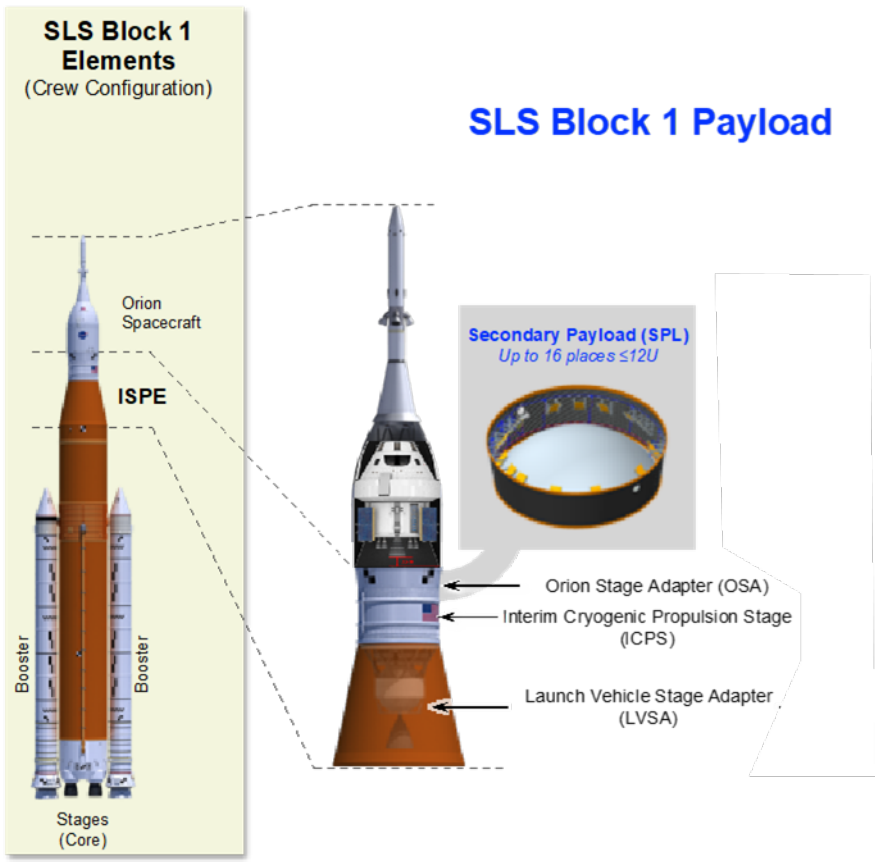

Figure 2 SLS Block 1 Integrated Spacecraft/Payload Element (ISPE)

4.1 Accommodations for SPL

SLS can accommodate SPLs, based on availability of excess capacity after accommodating: Orion (Block 1) for crewed missions. In general, SPL accommodations range from 6U (unit) to 12U class CubeSats. For SPLs with mission requirements that include separation from SLS, deployment begins post-TLI after Orion separation from ICPS and ICPS disposal initiation.

Secondary payloads interface to the Block 1 OSA via the Secondary Payload Deployment System (SPDS). The SPDS provides a standard SPL interface via a commercial off-the shelf (COTS) dispenser, dispenser/SPL support structure, Avionics Unit and cable harnesses for deployment signal and access to battery charging via the upper stage (provided by KSC ground services). Once Orion has separated from the upper stage and the upper stage has completed its disposal burn, SPLs can be deployed. Dispenser provided environmental interfaces for thermal, bonding/grounding, electromagnetic compatibility, venting, shock, and random vibration and load conditions.

SLS Block 1 will accommodate the SPDS on the inner surface of the OSA as shown in Figure 3.

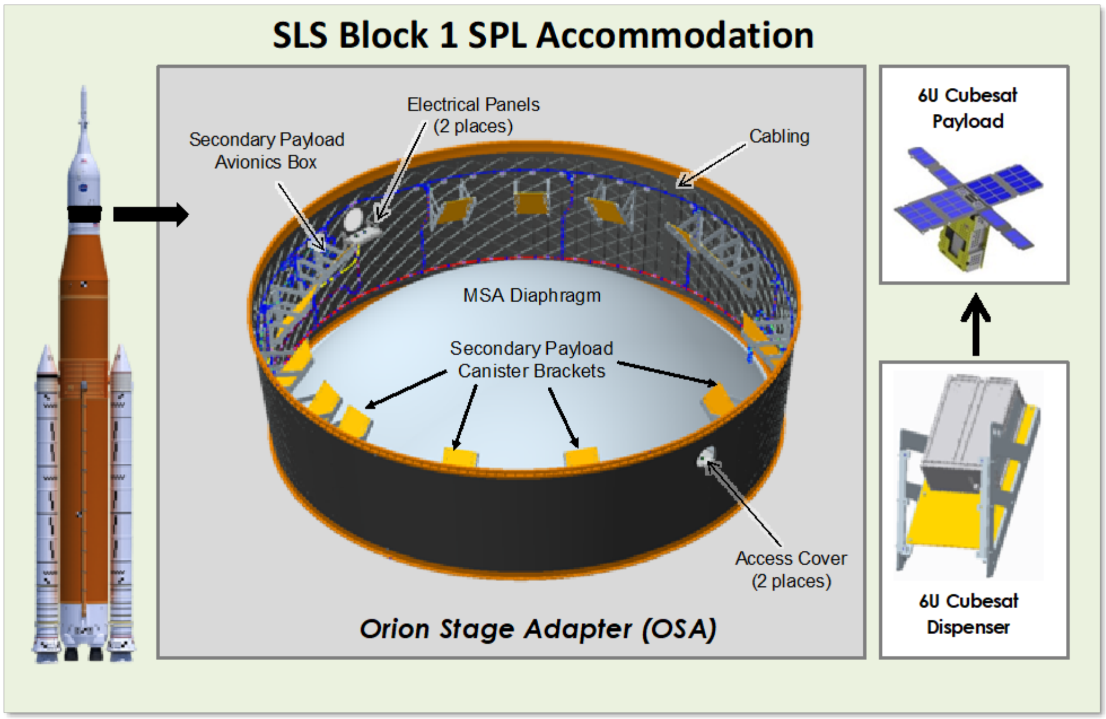

Figure 3 Orion Stage Adapter (OSA) to Integrated Secondary Payload (SPL) Interface

4.2 SPL Mechanical Interfaces

The primary structural interface for an SPL is to an SLS-specified COTS dispenser. This dispenser provides the SPL a means for SLS integration, protection during launch and ascent, and deployment from the SLS. The SPDS can accommodate either a 6U or 12U dispenser; the SPL must stay within allowed physical provisions for its associated dispenser. The SLS Block 1 OSA can physically accommodate up to 17 SPLs radially.

Physical provisions include the dimensional orientation of the payload inside the dispenser; maximum allowable dimensions, volume and mass; and the CG envelope. Figure 4 depicts the SPL dimensional orientation. Table 6 provides the dimensions, volume and mass numbers for both 6U and 12U dispensers. Figure 5 provides the payload CG datum within the dispenser. Table 7 provides the CG envelope numbers for 6U and 12U dispensers.

Based on the maximum allowable payload mass for a 6U dispenser (Table 6), an ejection rate of 3.9+/-0.2 feet/sec (1.2+/- 0.06 m/sec) is anticipated.

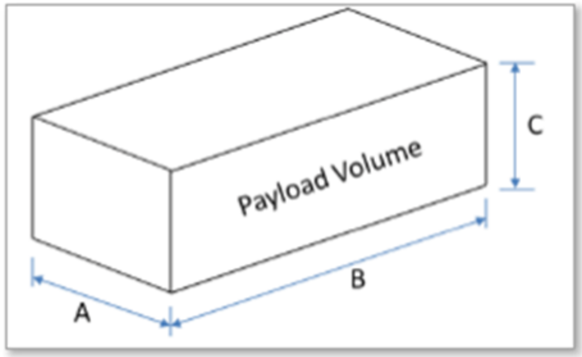

Figure 4 Secondary Payload (SPL) Envelope Dimensional Depiction

Table 6 Secondary Payload (SPL) Maximum Dimensions

Dispenser	A		B		C		Volume		Mass	
	in	mm	in	mm	in	mm	in^3	mm^3	lbm	kg
6U	9.41	239.00	14.41	366.00	4.45	113.00	603.41	9,884,562	30.86	14.00
12U	9.41	239.00	14.41	366.00	8.90	226.00	1206.82	19,769,124	44.73	20.29

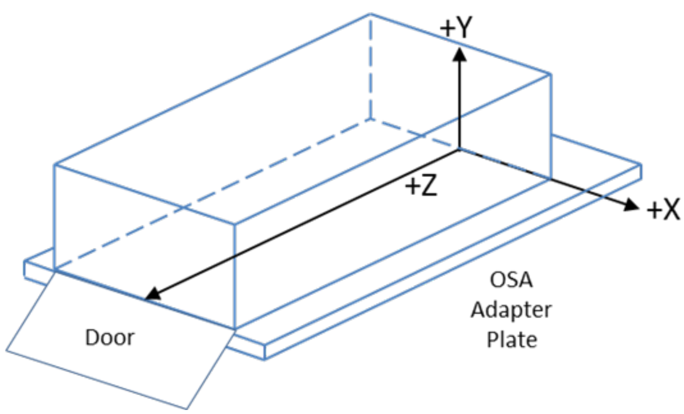

Figure 5 SPL Center of Gravity (CG) Envelope within Dispenser

Table 7 SPL Center of Gravity (CG) Envelope

Parameters	Units	6U		12U	
		Min.	Max.	Min.	Max.
Center of Mass, X	in (mm)	-1.50 (-38)	+1.50 (+38)	-1.57 (-40)	+1.57 (+40)
Center of Mass, Y	in (mm)	+0 (+0)	+5.00 (+127)	+2.17 (+55)	+4.92 (+125)
Center of Mass, Z	in (mm)	+6.00 (+152)	+9.50 (+241)	+5.24 (+133)	+9.17 (+233)

The integrated SPL/dispenser unit will interface with SLS for structural support (Block 1 OSA) during launch and early flight phases. The SPDS will provide the cable connectors and wire types that interface the integrated dispensers with the OSA support brackets. The integrated SPL/dispenser unit must be within the allowed mass and CG provisions of the OSA. Mass margin provisions for vibration isolation, thermal protection, etc. are an option and must be discussed with the SPIE office. The combined SPL/dispenser unit CG envelope is the same as shown in Table 7. The integrated SPL/dispenser unit will contribute to the combined loads as part of the encapsulated payload. These loads will be analyzed as part of flight/mission planning.

4.3 SPL Electrical Interfaces

In general, there is no capability for battery charging to SPLs, during VAB operations, or at the pad. Generally, the last opportunity for users to charge SPL batteries will be in standalone KSC facilities prior to vehicle stacking. SPL battery charging in the VAB via a drag on cable may be possible on a case-by-case basis as requested by the user. SPLs must remain powered off from handover to EGS at KSC until post-deployment from the SLS upper stage.

GSE connections are depicted in Figure 6. Only SPL systems using Lithium-ion 18650 rechargeable batteries can be charged at KSC prior to launch. SPLs will be delivered to KSC and inhibited from performing any functions until 15 seconds after deployment to minimize risk of hazardous operations during integration, launch and post-deployment.

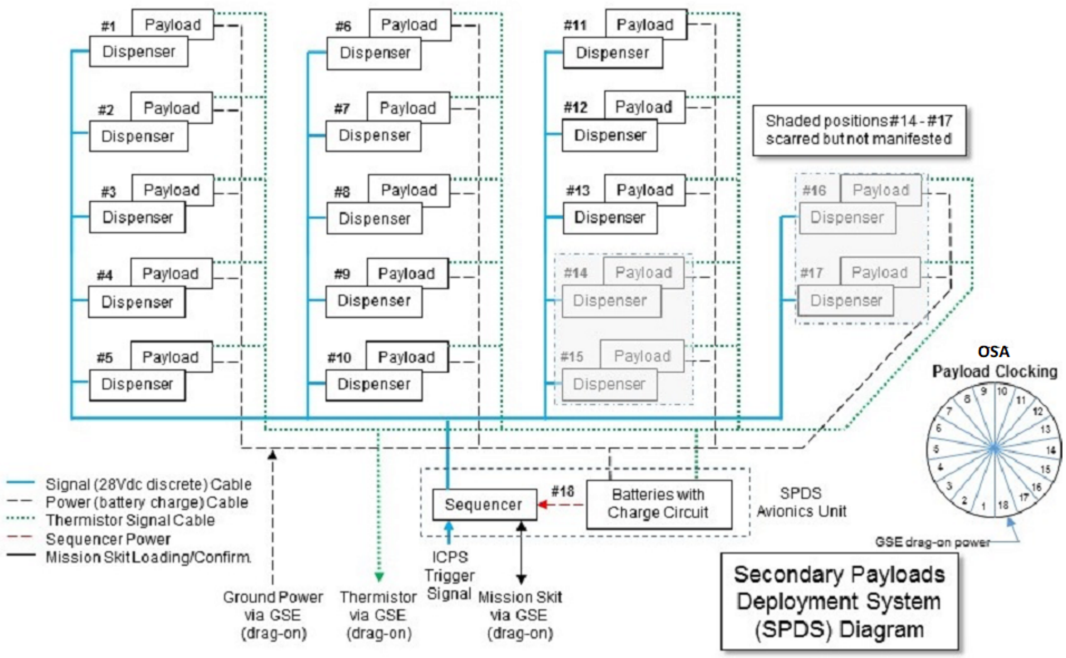

Figure 6 Representative SPDS Avionics Unit SPL Interface (Block 1/EM-1)

The AU has a battery life of up to 10 days after activation of the sequencer on-orbit. The sequencer activation is delayed until post-TLI and near completion of the upper stage disposal maneuver. SPLs using rechargeable batteries should be designed to support a launch no less than 180 days (nominal) after the last recharge. Approximately five minutes after the upper stage end-of-mission is complete (within eight hours from launch), the SPLs commence launching from OSA mounted dispensers.

5.0 Spacecraft/Payload Integration Documentation and Process

The products listed in this section define required spacecraft/payload services, interfaces and analysis to support all phases of the integration process. Based on the complexity of a specific spacecraft/payload, additional information may be required.

5.1 Payload Integration Agreement (PIA)

The PIA, or an equivalent programmatic agreement, establishes and implements all management and programmatic integration requirements between the spacecraft/payload and SLS. The PIA defines SLS and the spacecraft/payload roles and responsibilities, interfaces, standard services, any non-standard services, deliverable exchanges and the overall schedule for successful integration and launch. The PIA is developed by the PIM and coordinated with the spacecraft/payload, with revisions negotiated and agreed to by all parties as needed. SPIE will work with ESD, ESG and the spacecraft/payload early in the development process to develop a draft PIA using the spacecraft/payload IRD or equivalent document; all parties will agree to a draft of the document prior to formal manifesting. When ESD manifests the spacecraft/payload on SLS, the PIA will be baselined. Baselining the PIA formally starts the SLS-spacecraft/payload integration process.

5.2 Payload Unique Interface Control Document (ICD)

The SLS payload unique ICD defines the interface and requirements between SLS and EGS, and the spacecraft/payload for a specific mission. The ICD is the agreed upon design solution that controls and defines each side of an interface (SLS or spacecraft/payload) for hardware, GSE, software and environment compatibility. The SPIM (Secondary Payload Integration Manager) develops ICD in coordination with the spacecraft/payload. As part of this payload unique ICD, a verification plan will provide one-to-one mapping of spacecraft/payload requirements to a particular compliance method for all phases of operations (e.g., ground processing, lift-off, in-flight, SLS separation events). The verification plan provides instructions and guidelines to verify safety and interface compatibility of the as-built SLS vehicle and spacecraft/payload hardware and software. The success criteria and methods of verification will be in the form of Detailed Verification Objectives (DVO), outlining the type or proof required for closeout (e.g., test, analysis, demonstration, inspection, similarity, and/or validation of records).

5.3 Payload Unique Safety Requirements Document (SRD)

A SLS safety representative establishes the safety policy and requirements applicable to SLS spacecraft/payload for a specific mission in the payload unique SRD. Its typical scope starts at payload delivery at the launch site and continues through ascent until end of the Orion mission or until upper stage disposal. For the ground processing phase, the payloads must also comply with identified ground processing hazard requirements as identified in this document. Verification results of these payload ground and flight processing/operations hazards will be reviewed at the relevant phase Payload Safety Reviews.

5.4 Payload Safety Reviews (PSRs)

PSRs will be phased over time and require information to perform analysis efforts that include, but are not limited to, payload handling and physical processing hazards, RF interference, ascent hazard, debris characteristics for input to unique range safety data, joint loads and environments, payload recontact analysis (nominal mission scenarios), etc. The spacecraft/payload will be required to participate in these and support data requests from the Payload Safety Review Panel (PSRP). Flight and ground safety requirements will be documented in the SRD and will form the basis of verification according to the corresponding hazard.

The following are excerpts from the Secondary Payloads Interface Definition & Requirements Document (IDRD, SLS-SPIE-RQMT-018). Modifications have been made to reflect EM-2 current configuration.

6.0 Payload Environments

6.1 Ejection Rate

Secondary payloads will deploy with an ejection rate (deployment velocity) range as shown in Figure 7 based on the maximum allowable payload mass from a 6U configuration. Spring rates for 12U cubesats has not been determined but should be comparable to a 6U.

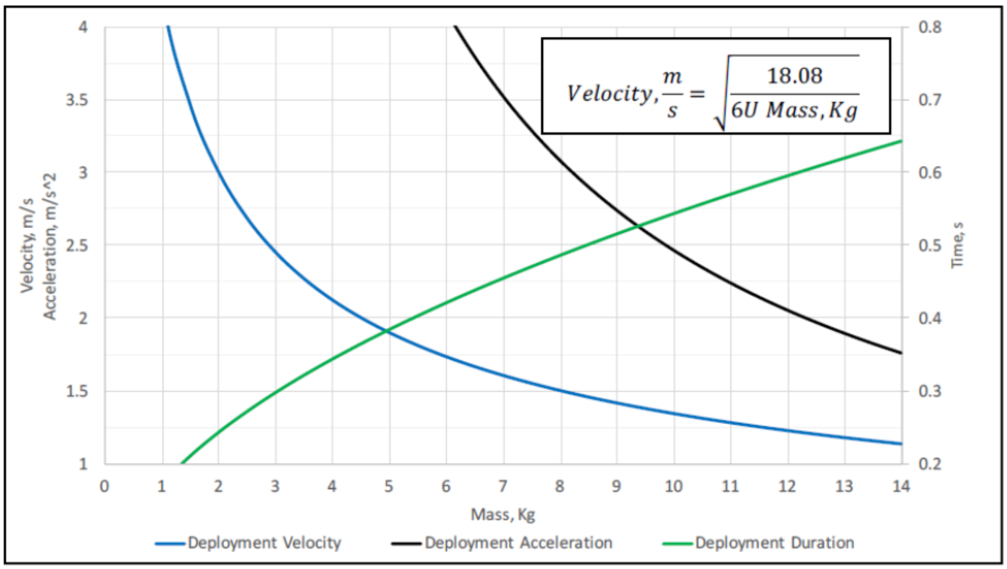

Figure 7 – Ejection Velocity

6.2 Storage

Integrated secondary payloads will be storable up to 6 months (nominal duration) under VAB environmental conditions listed in Table 8.

Table 8 Vehicle Assembly Building (VAB) Environmental Conditions

	Minimum	Maximum
Temperature	39.7 °F (Winter)	89.6 °F (Summer)
Humidity (Informational)	18.1% (Winter)	98.9% (Fall)

6.3 Radiation

The dispenser and those payloads containing radiation sensitive propellant could experience all ionizing radiation during and after exposure to the in-space radiation environments range identified in Figure 8.

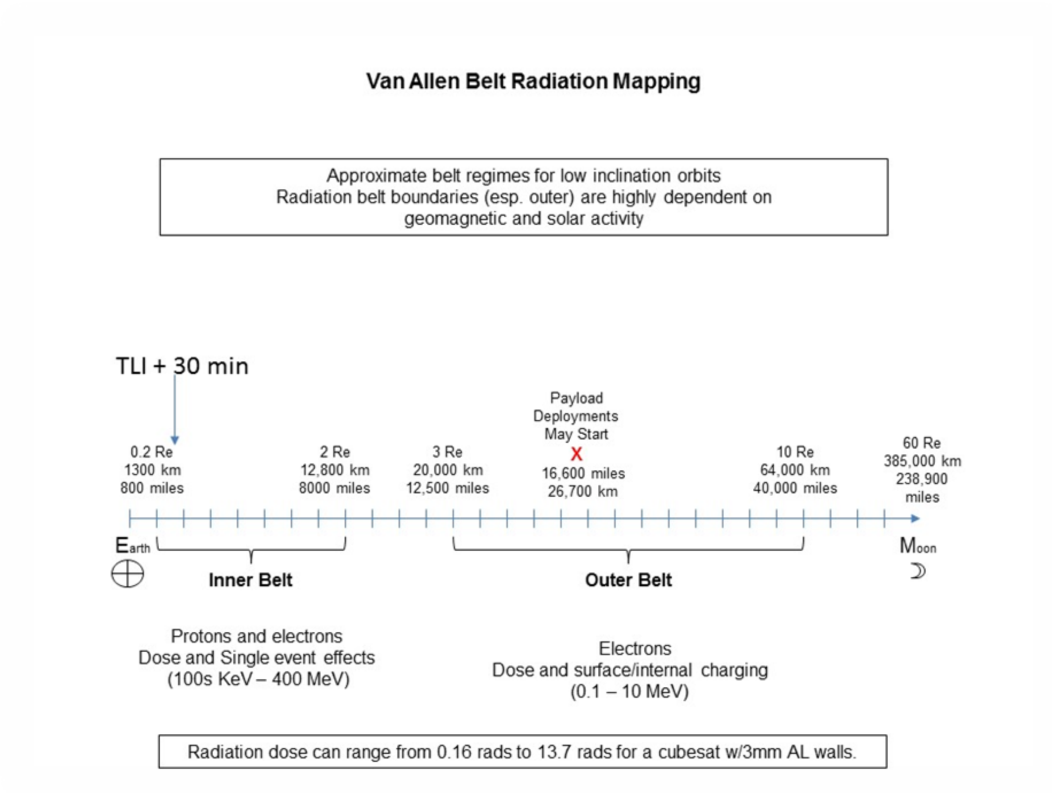

Figure 8 Van Allen Belt Radiation Mapping

6.4 Venting

The dispenser and any vented containers within the secondary payloads EM-1 MPCV/MSA shared compartment (above the MSA diaphragm) shall size vent flow areas such that structural integrity is maintained with required FoS per NASA-STD-5001 for the maximum pressure differential created by SLS ascent (average value is 0.15 psi/sec with peaks at 0.5 psi/sec). For venting design purposes, the payload compartment depressurization environment will be no more severe than as depicted in Figure 9.

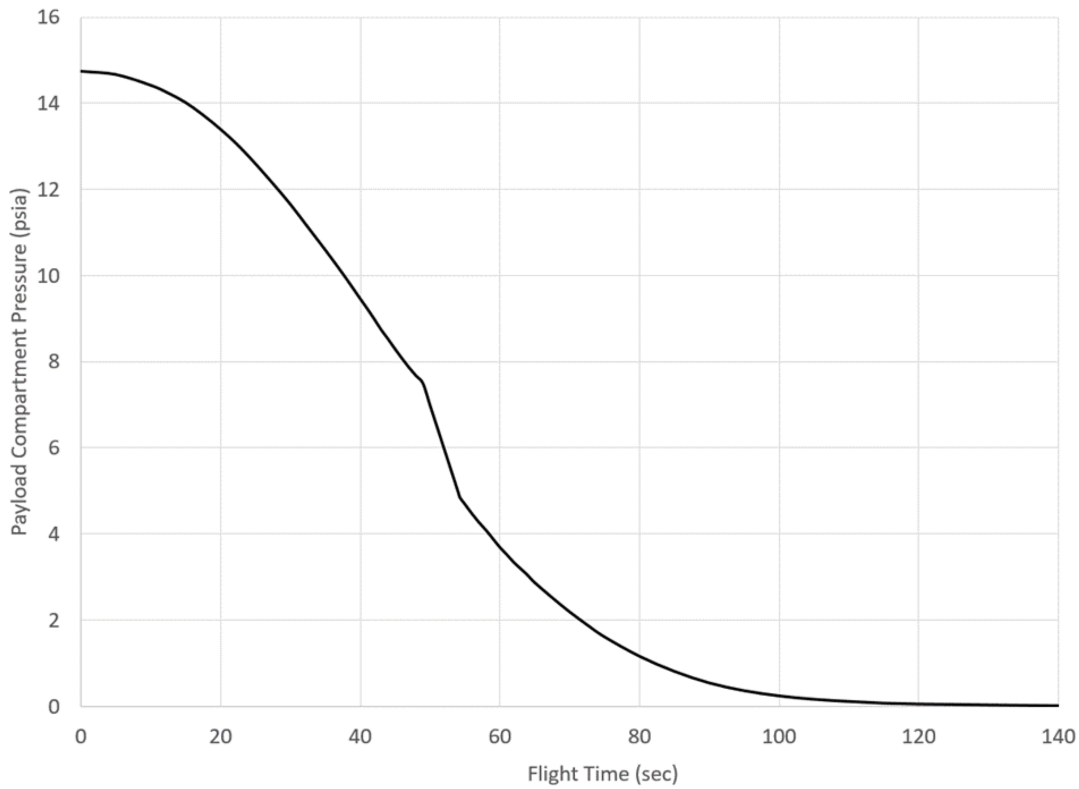

Figure 9 Depressurization Environment

6.5 Random Vibration Levels

The isolated random vibration levels, at the base of the dispenser, are given below in Figure 10 and Table 9. This includes a vibration isolation system between the dispenser and the vehicle mounting bracket for a 6U cubesat configuration. 12U levels have not been determined at this time. But they should be comparable as the 6U.

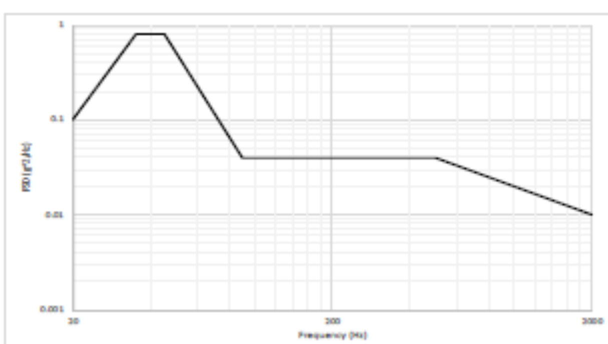

Figure 10 Isolated Random Vibration Levels

All Axis	
Frequency (Hz)	PSD (g^2/Hz)
20	0.10
35	0.79
45	0.79
90	0.04
500	0.04
2000	0.01
Composite = 8.2 grms	
Test Duration: 60 seconds/axis	

Table 9 Secondary Payload Random Vibration Qualification Test Levels for Flight

7.0 Payload Constraints

Integrated secondary payloads shall not exceed a payload mass of 30.86 lbm (14 kg) for a 6U configuration. Tentatively the maximum mass of a 12U Cubesat shall be 44.73 lbm (20.29 kg).

Conductive surfaces for secondary payloads shall be electrically bonded per NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment. For metalized Multilayer Insulation (MLI), Class S, Electrostatic Discharge, requirements apply. A Class H bond is required through the pigtail cable harness shield that is connected to the payload separation connector.

Any secondary payloads lasers that are accessible during ground processing shall be designed and operated in accordance with American National Standard for Safe Use of Laser, ANSI-Z-136.1.

Any secondary payload having pyrotechnic subsystems or devices shall meet the design and test requirements of MSFC-SPEC-3635, Pyrotechnic System Specification.

Secondary payloads shall restrict payload volume expansion of its launch configuration for a minimum of 15 seconds following deployment unless the deployed payload is within a 40” X 40” X 40” envelope centered on the volumetric center of the CubeSat.

Secondary payloads shall have one Radio Frequency (RF) inhibit for power output that is less than 1.5Watt (W) or two independent RF inhibits for power output equal to or greater than 1.5W.

The secondary payloads shall have, at a minimum, 2 deployment switches, which are actuated while integrated in the dispenser.

Many propulsion systems are allowed with the exception of hydrazine and cryogenic systems. Propulsion systems will be subjected to the payload safety panel for approval.

8.0 Payload Power

Secondary payload electrical power distribution circuitry shall be designed to include circuit protection devices to protect against circuit damage normally associated with an electrical fault when such a fault could result in damage to the SLS.

A payload that requires battery charging prior to launch while at KSC must meet the following conditions in this section.

- The payload shall contain reverse current circuit protection in the positive leg of the charging circuit to the battery.
- The payload shall contain a 10K thermistor within the battery pack with the leads made available to an external connector.
- The payload shall have the charging circuit separate from the payload system's circuit.
- The payload shall use Li-ion 18650 rechargeable batteries along with a battery management system to provide protection for overcharge, over-discharge, over-current, over-heating, and dual short circuit protection.

9.0 Payload Structural

The structural design of the secondary payload primary structures, including pressure vessels and pressure systems, shall be in accordance with NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight hardware, demonstrating positive margins of safety against the required minimum factors of safety and test factors provided in NASA-STD-5001 for all applicable mission phases as defined in this document.

Secondary payloads pressure-stabilized vessels shall not be used on SLS EM-1 Secondary Payloads.

Secondary payload sealed containers shall be designed to withstand the maximum pressure differential created by SLS ascent of 15.2 psi in accordance with requirement 6.1.4 in NASA-STD-5019.

Secondary payloads shall provide a Materials and Processes assessment per requirements in NASA-STD-6016. This assessment will be documented in a final Certification Material Usage Agreement (MUA) that includes a brief description of the payload and the final Materials Identification and Usage Lists (MIUL) along with any required MUAs. The Materials and Process Technical Information System (MAPTIS) rating system for metallic and nonmetallic materials will be used for this assessment.

10.0 Payload Responsibilities

The payloads are responsible for securing their radio frequencies and arranging any ground communication services (i.e. amateur radio, near earth network, deep space network, etc.). Once the vehicle and Orion establish their frequencies the payload will need to determine their frequencies do not interfere with those frequencies.

Secondary payloads shall show compliance with NASA Procedural Requirements (NPR) 8020.12, Planetary Protection Provisions for Robotic Extraterrestrial Missions.

Secondary payloads shall comply with the requirements in NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris.

11.0 Provided Items to the Payloads

Items to be provided to the payload developers are:

- A flight dispenser shall be provided to each payload on a reimbursable basis by the project office.
- The project office will make available a non-flight dispenser for up to 2 payload fit checks.
- The project office will provide flight 18650 battery cells to the payloads for those wishing to have their batteries charges in the OSA prior to stacking of the vehicle. Said payloads will also need to meet the earlier mentioned battery/circuit protection requirements. Payloads wishing to use their own batteries must meet JSC 20793 Rev. C.

This list of conditions is not all inclusive. As the mission definition matures, more information/conditions will be added/updated. For more information, please refer to the SLS Misson Planners Guide (ESD 30000 Rev A., 12/19/18) at https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005323.pdf

or questions may be sent via email to: nasa-slspayloads@mail.nasa.gov